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DRAG AND LOSS OF SPIN OF BRITISH 3 INCH SHELL

by

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Abstract

The drag coefficients of two forms of British 3" shell are compared to those of similar American shells, and found to agree quite well. The spin coefficient of one of the British shells is determined from drift data.

1. OBJECT: Messrs. Fowler, Gallop, Lock, and Richmond* obtained aerodynamical data for a 3 inch shell with two different heads. The drag coefficients for both forms were determined as functions of the velocity: these will be compared to the drag coefficients of somewhat similar American 3 inch shells. Also, the drift of one form was computed, on the assumption that there was no loss of spin, and compared to observations: an empirical spin coefficient will be determined from these data.

2. PROJECTILES: Form A is a 16 lb. H.E. Shell Mark IIB with a fuze No. 80 Mark III (Fig. 1). Form B is the same shell with a 6 caliber radius head (Fig. 3). The contours and dimensions are shown in Fowler's figure 6. The shell has a square base, and the British Mark III fuze is equivalent to about a 2 caliber radius head. Form A is similar to our A.A. Shell Mark IX with the Scovill Fuze Mark III (Fig. 2). Form B is similar to our 15 lb. Shell M1915 (Fig. 4).

* "The aerodynamics of a spinning shell". Phil. Trans. Royal Soc. London, A, 221, 295-387, (1920).

3. <u>DRAG</u>: Fowler's curve III of Fig. 4 and curve II of Fig. 5 are plots of the drag coefficient (in terms of the radius) against the ratio of projectile velocity to sound velocity in air. These curves are reproduced on the inclosed plots (Figs. 5 and 6), together with similar curves for the American shells, based on data obtained at Aberdeen.* The non-dimensional drag coefficient shown here is defined by the formula:

$$K_D = \frac{D}{\rho d^2 u^2},$$

where

D is the drag,

ρ is the density of the air,

d is the caliber,

u is the velocity of the projectile relative to the air.

These values are for zero yaw. The curves were extrapolated for u/a less than 0.5: the Bureau of Standards later determined the drag coefficient of the Mark IX Shell at ratios less than 0.2, and found that it was practically constant. In the regions where the resistance firings were conducted, the British and American curves agree remarkably well.

4. <u>DRIFT</u>: Fowler's table VIII gives calculated trajectory and drift data for shell of form A, fired at a muzzle velocity of 2000 ft/sec and elevations of 50° and 30°. Table IX gives observed and calculated values of the ratio of drift to time, for guns rifled 1/30 and 1/40, fired in February and again in April and May of 1918. The drift deduced from this ratio is tabulated in the inclosed table. This table also shows the drift calculated with a variable spin: the spin coefficient assumed for this purpose was

$$C_A = 1.74 \times 10^{-8} \text{ lb.ft/in}^4,$$

which was derived by Kent** from experiments with a 3.3" shell.

* "Report on program of resistance firings of 3" A.A. Shell Mark IX, Fuze Mark III". O.P. 4339; T.S.T.P. 1922-112, 10th Add. "Report on Resistance of 3" common steel shell Model 1915". O.P. 4866; T.S.T.P. 1927-469.

** "A Determination of the loss of spin of projectiles". A.P.G. B.R.L. Report 154 (1939).

5. COMPUTATION OF DRIFT: The loss in spin was determined by numerically solving the differential equation:

$$d \log_e N = - \frac{C_A d^4}{A} \rho u \, dt,$$

where

N is the spin,

d is the caliber in inches,

A is the axial moment of inertia in $lb.ft^2$,

ρ is the relative air density as a function of altitude,

u is the projectile velocity in ft/sec,

t is the time in sec.

The drift was then computed by Fowler's equations (4.203) and (4.204), with values of f_L/f_M taken from Fig. 15*.

6. COMPARISON: If D_o denotes the observed drift, the percentage error in the calculated drift D_c is defined as

$$100 \frac{D_c - D_o}{D_o} .$$

The values for times less than 9 sec. are evidently erratic, and were disregarded. A weight of $D_o^{3/2}$ was assumed for the others. The weighted mean percentage errors are:

- 3.90 for the variable spin,

+ 8.27 for the constant spin.

7. SPIN COEFFICIENT: By interpolating linearly between these values, we find that the mean error would be zero if the spin coefficient were 0.68 of the assumed value,

* This ratio, divided by the square of the velocity, is tabulated in Hitchcock's "Drift", A.P.G. B.R.L. file A-IV-29 (1926).

or

$$C_A = 1.18 \times 10^{-8} \text{ lb.ft/in}^4.$$

If consistent units were used, the spin coefficients would be non-dimensional, and their values would be:

$$K_A = 0.0048 \text{ for the 3.3" shell,}$$

$$K_A = 0.0033 \text{ for the British 3" shell.}$$

The relation between the non-dimensional and the "practical" coefficients is:

$$K_A = 2.760 \times 10^5 \, C_A.$$

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Drift of British 16 lb. 3" Shell of Form A

Month Fired	Elevation deg.	Twist of Rifling rev/cal.	Mean Observed Time sec.	Drift (min.) Calculated Var. N.	Observed	Calculated Const. N
April May	50	1/30	10.9	13.0	15.9	13.8
			23.9	49.3	53.5	54.7
			33.3	86.8	96.2	94.9
			41.3	120.5	130.5	138.7
"	"	1/40	10.2	8.7	12.0	9.2
			22.9	34.3	29.8	38.0
			31.0	57.7	60.5	65.1
			39.1	83.7	78.2	95.4
"	30	1/30	10.04	10.6	9.8	10.5
			20.6	33.8	32.4	36.5
			27.9	53.1	58.3	57.5
"	"	1/40	9.58	7.4	15.6	7.6
			19.35	23.5	15.5	24.8
			25.95	36.0	27.0	38.9
Feb.	50	1/30	6.99	5.8	31.7	6.0
			15.03	22.5	25.2	24.8
			26.08	57.3	51.9	64.2
"	"	1/40	6.33	3.6	22.9	4.0
			14.07	15.1	19.7	16.6
			24.93	39.7	36.6	46.4
"	30	1/30	13.2	17.2	18.5	17.4
			22.52	39.1	30.6	41.9
"	"	1/40	13.02	12.6	22.5	12.6
			22.05	28.5	27.6	30.4

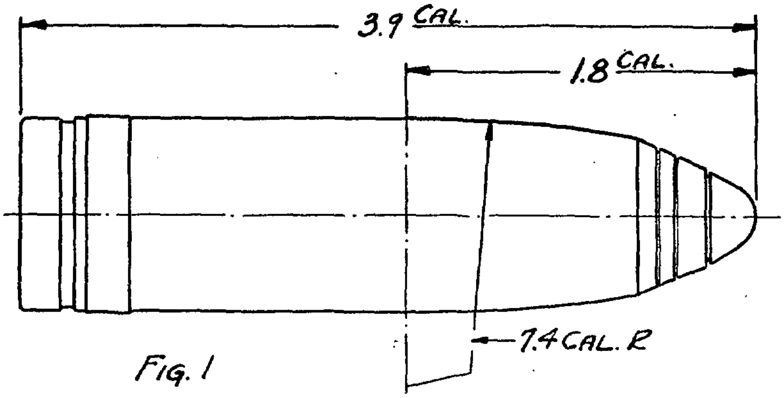


FIG. 1

SHELL, 3" A.A., BR., MK. IIB ; FUZE, NO. 80 MK. III.

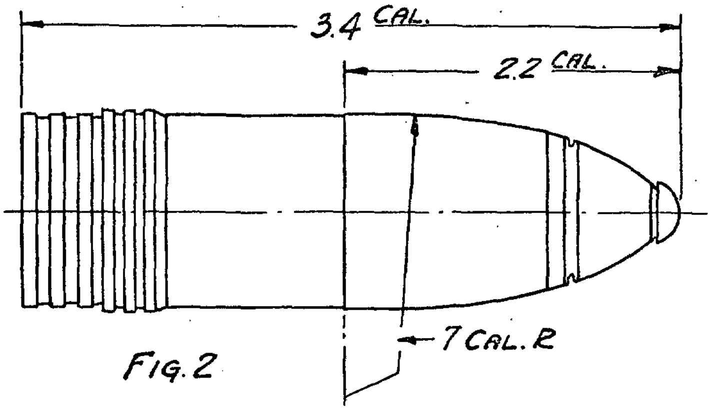
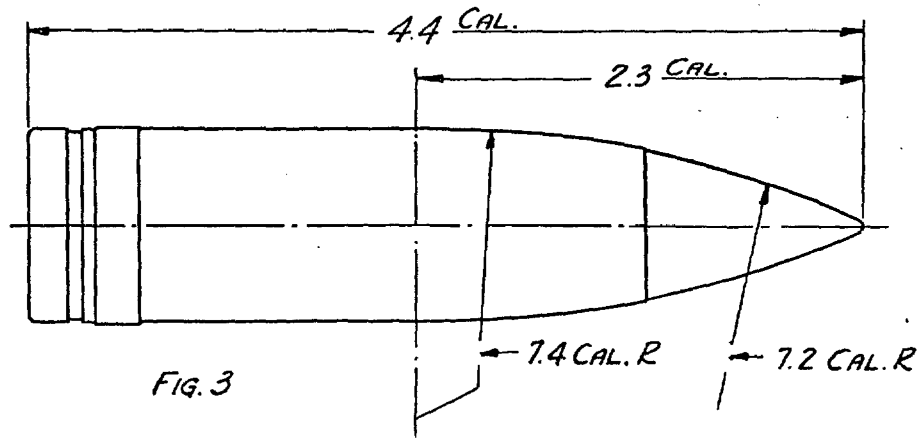
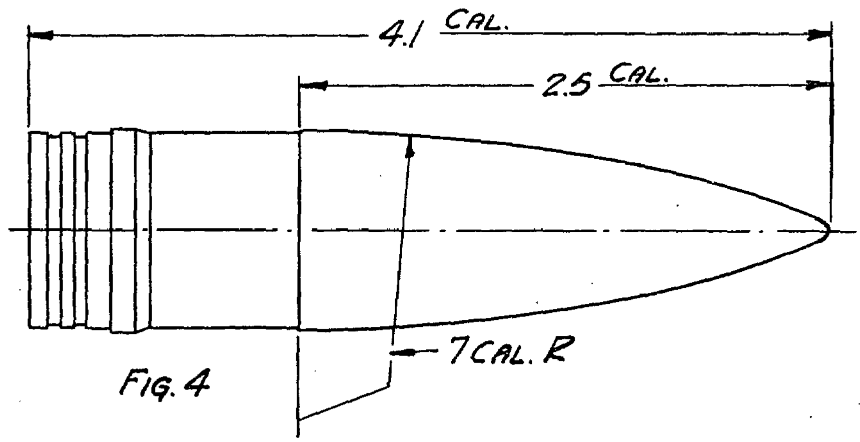


FIG. 2

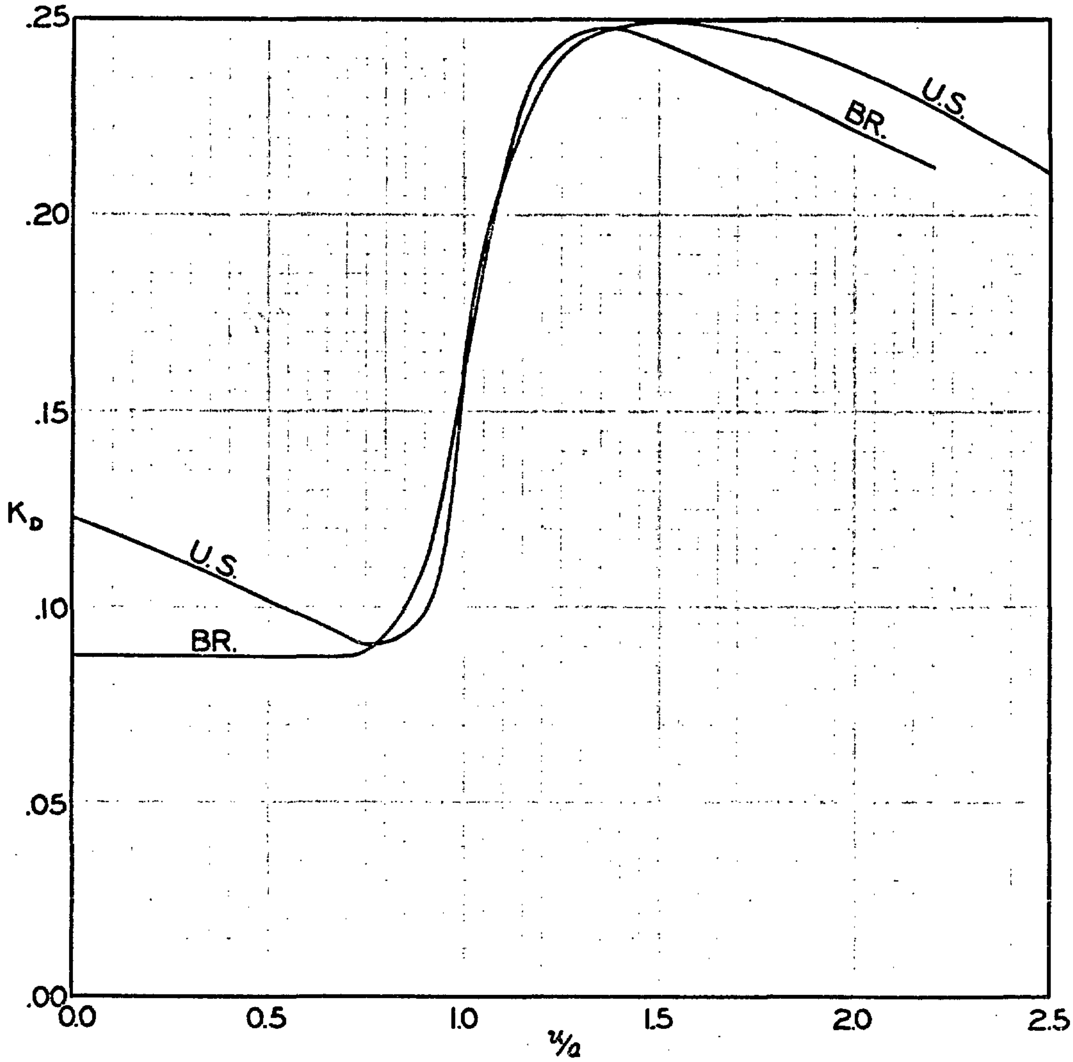
SHELL, 3" A.A., U.S. MK. IX ; FUZE, TIME, MK III



SHELL, 3" H.E., BR., MK IIB; FUZE, C.R.H PLUG, DESIGN 25420



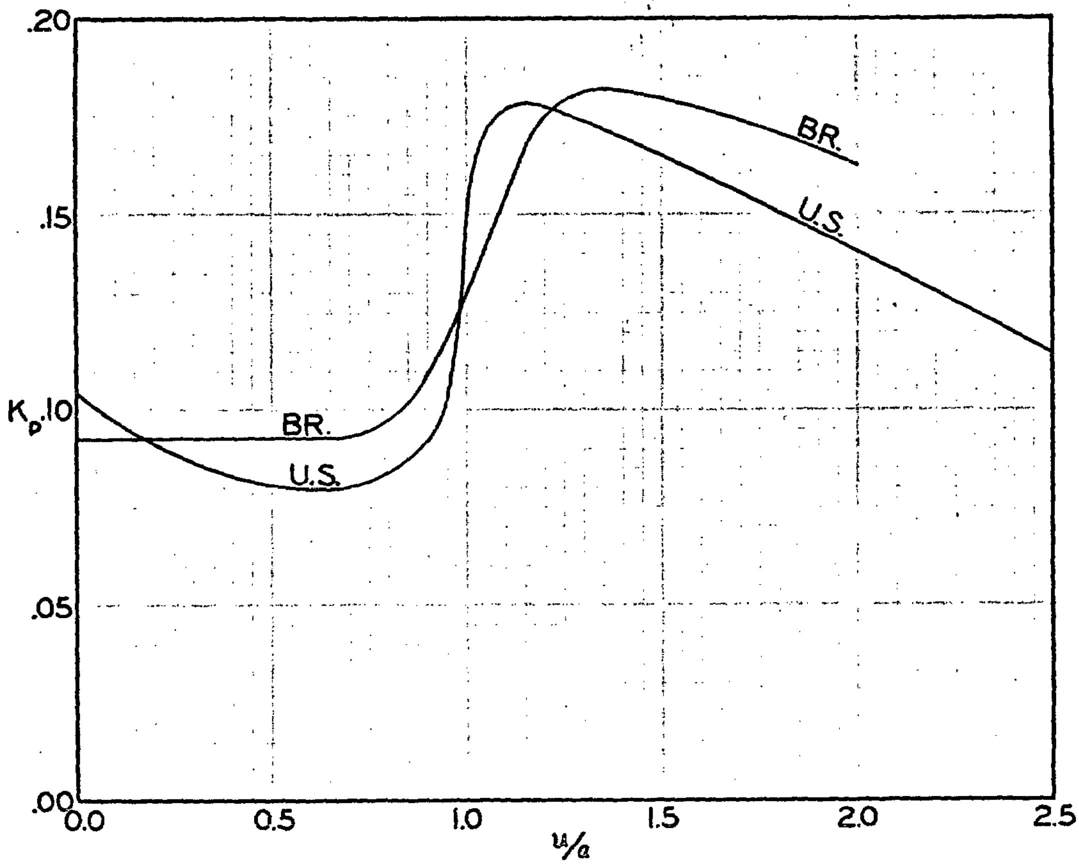
SHELL, 3" H.E., MODEL 1915; FUZE, B.D. MK. V



DRAG COEFFICIENT, K_D
VS.
MACH'S RATIO u/a

	BR.	U.S.
PROJECTILE	FORM A	TYPE 3
3" SHELL	BR. H.E. MK.IIB	U.S. A.A. MK. IX
FUZE	NO. 80 MK. III	TIME, MK. III
WEIGHT-LBS.	16	12.7
OGIVAL HT.-CAL.	1.802	1.622
OGIVAL RAD.-CAL.	2	2
BASE	SQUARE	SQUARE

- FIG. 5 -



DRAG COEFFICIENT, K_D
VS.
MACH'S RATIO u/a

	BR.	U.S.
PROJECTILE	FORM B	TYPE 6
3" SHELL	BR. H.E. MK.II B	U.S. H.E. M1915
FUZE	6 CRH PLUG	B.D. MK V
WEIGHT – LB.	16	15
OGIVAL HT. – CAL.	2.328	2.527
OGIVAL RAD.– CAL.	6	7
BASE	SQUARE	SQUARE

– FIG. 6 –

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ABSTRACT:

Aerodynamical data were obtained for a British 3" shell with two different heads. The heads were of 2 and 6 calibers, respectively, with the smaller being similar to the US anti-aircraft shell, Mark IX, and the larger resembling the US M1915 shell. The data collected from the tests included the drag coefficients and the drift tendencies of each type. The drag coefficients of the two British shells were compared with the similar type US shells, and found to agree quite well. Also, the spin coefficient of one of the British shells was determined from the drift data.

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